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Earth-moving machinery — Wheeled machines — Steering requirements

Engins de terrassement — Engins équipés de pneumatiques — Systèmes de direction

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 127, *Earth-moving machinery*, Subcommittee SC 2, *Safety requirements and human factors*.

This fourth edition cancels and replaces the third edition (ISO 5010:2007), which has been technically revised.

The main changes compared to the previous edition are as follows:

— the title has been changed to “Wheeled machines” to include machines with drums and crawler wheel assemblies;

— requirements have been provided for earth-moving machinery (EMM) with a maximum machine speed <20 km/h.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document is a type-C standard as stated in ISO 12100.

This document is of relevance, in particular, for the following stakeholder groups representing the market players with regard to machinery safety:

— machine manufacturers (small, medium and large enterprises);

— health and safety bodies (regulators, accident prevention organisations, market surveillance etc.).

Others can be affected by the level of machinery safety achieved with the means of the document by the above-mentioned stakeholder groups:

— machine users/employers (small, medium and large enterprises);

— machine users/employees (e.g. trade unions, organizations for people with special needs);

— service providers, e. g. for maintenance (small, medium and large enterprises);

— consumers (in case of machinery intended for use by consumers).

The above-mentioned stakeholder groups have been given the possibility to participate at the drafting process of this document.

The machinery concerned and the extent to which hazards, hazardous situations or hazardous events are covered are indicated in the Scope of this document.

When requirements of this type-C standard are different from those which are stated in type-A or type-B standards, the requirements of this type-C standard take precedence over the requirements of the other standards for machines that have been designed and built according to the requirements of this type-C standard.

As functional safety of steering system is not covered in this document, guidance for functional safety of steering systems can be found in the following standards: ISO 15998, ISO/TS 15998-2, ISO 13849-1, ISO 19014-1, ISO 19014-2[1)], ISO 19014-3, ISO 19014-4[2)] and ISO/TS 19014-5[3)].

1) Under preparation. Stage at the time of publication: ISO/DIS 19014-2:2019.

2) Under preparation. Stage at the time of publication: ISO/DIS 19014-4:2019.

3) Under preparation.

Earth-moving machinery — Wheeled machines — Steering requirements

1 Scope

This document specifies steering system tests and performance criteria for evaluating the steering capability of wheeled, ride-on earth-moving machinery as defined in ISO 6165:2012. Wheeled machines include machines equipped with wheels, one or more drums or crawler wheel assemblies.

This document deals with the following significant hazards, hazardous situations or hazardous events relevant to wheeled machines, when used as intended and under conditions of misuse which are reasonably foreseeable by the manufacturer:

— mechanical hazards;

— ergonomic hazards;

— hazards due to maintenance;

— hazards due to the control system;

— hazards related to travelling function.

Functional safety of the steering system is not covered in this document.

This document is not applicable to wheeled machines manufactured before the date of its publication.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 3450:2011, *Earth-moving machinery — Wheeled or high-speed rubber-tracked machines — Performance requirements and test procedures for brake systems*

ISO 6016:2008, *Earth-moving machinery — Methods of measuring the masses of whole machines, their equipment and components*

ISO 7457:1997, *Earth-moving machinery — Determination of turning dimensions of wheeled machines*

ISO 12100:2010, *Safety of machinery — General principles for design — Risk assessment and risk reduction*

ISO 10968:—[4)], *Earth-moving machinery — Operator's controls*

ISO 18752:2014, *Rubber hoses and hose assemblies — Wire- or textile-reinforced single-pressure types for hydraulic applications — Specification*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12100 and the following apply.

4) Under preparation. Stage at the time of publication: ISO/DIS 10968:2019.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
steering system
system including all machine elements between the operator and the ground-contacting *wheels* (3.2), drums or *crawler wheel assemblies* (3.3) participating in steering the machine

3.1.1
manual steering system
steering system (3.1) depending exclusively on the muscular power of the operator to affect steering of the machine

3.1.2
powered steering system
steering system (3.1) employing auxiliary power sources to supplement or replace the muscular power of the operator to affect steering of the machine

3.1.3
primary steering system
steering system (3.1) used to steer the machine when the steering system functions as intended

3.1.4
secondary steering system
steering system (3.1) used to steer the machine in the event of a loss of the *primary steering power source* (3.5.1)

3.2
wheel
circular structure able to rotate on an axle, either directly or with the use of bearings, with the external part in contact with the ground

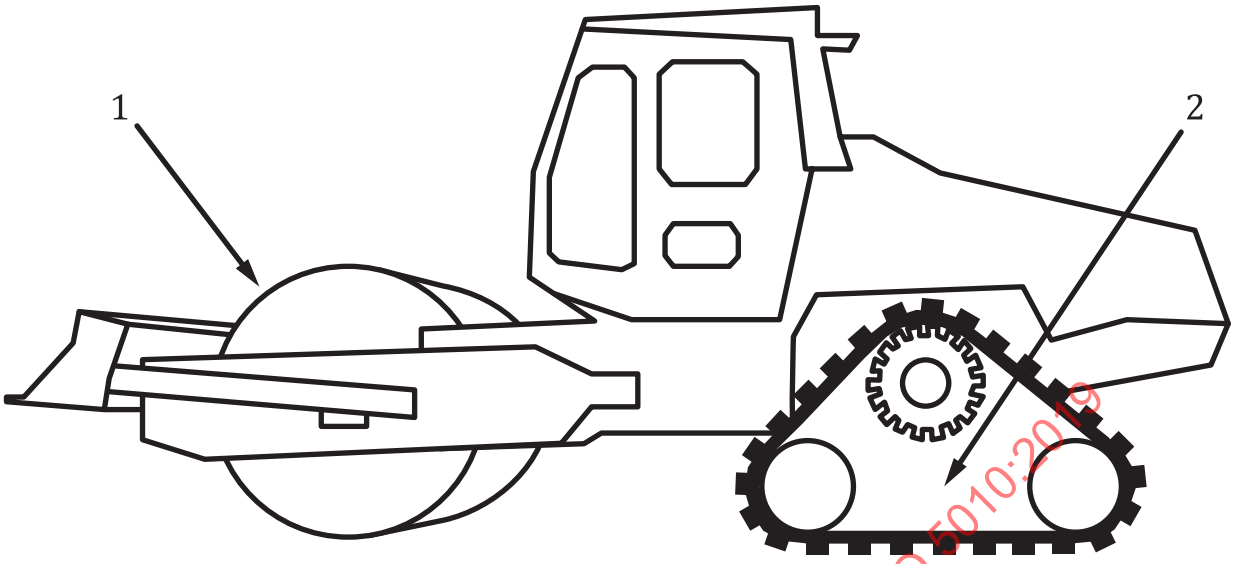
3.3
crawler wheel assembly
crawler system used in place of a *wheel* (3.2) on a single axle

Note 1 to entry: See Figure 1.

Note 2 to entry: Machines with crawler wheel assemblies are steered using techniques common to rubber-tyred machines, for example Ackermann steering, articulated steering.

3.4
wheeled machine
machine on *wheels* (3.2), drums or *crawler wheel assemblies* (3.3)

Note 1 to entry: See Figure 1.



Key

1 drum

2 crawler wheel assembly

Figure 1 — Wheeled machine with drum and crawler wheel assemblies

3.5 steering power sources

3.5.1
primary steering power source
means for providing power to effect steering in a *powered steering system* (3.1.2)

EXAMPLE Hydraulic pump, air compressor, electric generator.

3.5.2
secondary steering power source
means for providing power to the *secondary steering system* (3.1.4) in the event of *primary steering power source failure* (3.5.3)

EXAMPLE Hydraulic pump, air compressor, accumulator, battery.

Note 1 to entry: It is assumed that not more than one failure will occur at the same time.

3.5.3
primary steering power source failure
complete and instantaneous loss of the *primary steering power source* (3.5.1)

3.6
steering control element
control element used by the operator to transmit the steering command for the desired direction or to control the relative speed of the left-hand and right-hand sides of the drive system

EXAMPLE Steering *wheel* (3.2), lever controls, joystick controls, pushbutton/touch pad controls and foot pedal controls.

Note 1 to entry: For a machine that has equal alternative operator's position both at the left-hand and right-hand sides of the machine equipped with a conventional steering wheel at each position (e. g. some types of rollers), these two steering wheels are considered as one steering element.

3.6.1
principal steering control element
steering control element (3.6) at the operator's positions that is primarily used to fulfil the primary steering and, if applicable, the secondary steering

3.6.2
alternative steering control element
additional *steering control element* (3.6) that can be used instead of the *principal steering control element* (3.6.1) to fulfil primary steering

3.7
steering effort
necessary force exerted by the operator on the *steering control element* (3.6) in order to steer the machine

3.8
steering angle
total displacement angle between the front *wheels* (3.2) and the rear wheels as they move about one or more vertical steering axes from their normal straight-ahead condition to a turned condition

Note 1 to entry: The steering angle for multiple-axle machines is determined between the wheels at the farthest forward and farthest rearward axles.

Note 2 to entry: Ackermann steering inherently has a greater steering angle on the side of the machine toward the inside of the turn as compared to the wheels on the outside of the turn. Therefore, where Ackermann steering is involved, the location of the steering angle measurement also needs to be specified.

Note 3 to entry: A steering angle accomplished by a combination of geometries incorporating Ackermann steering is included, and also requires the location of the steering angle measurement to be specified.

3.9
width over wheels
distance on Y coordinate between two Y planes passing through the farthest points of the machine on both sides of the zero Y plane measured at the location of the *wheels* (3.2)

3.10
outer wheel clearance diameter
diameter of the circular path described by the outermost point of the loaded (lower) section of the *wheel* (3.2) located on the vertical diameter of the outermost wheel when the machine is executing its sharpest practical turn under the conditions described in ISO 7457:1997, Clause 7

3.11
wheel circle
outer wheel clearance diameter (3.10) determined in accordance with Clause 7

3.12
maximum machine speed
maximum speed determined in accordance with ISO 6014

[SOURCE: ISO 3450:2011, 3.12, modified — The words ", or equivalent" have been removed.]

4 General requirements

4.1 General

Earth-moving machinery shall comply with the safety requirements and/or protective measures of this clause, unless modified by requirements of the relevant specific part of the standard series. In addition, the machine shall be designed according to the principles of ISO 12100:2010 for hazards relevant but not significant which are not dealt with by this document.

4.2 Required steering systems

4.2.1 All machines shall have a primary steering system.

4.2.2 Machines with a maximum machine speed ≥20 km/h shall have a secondary steering system. This does not apply to machines equipped with a manual steering system as the primary steering system.

4.3 All steering systems

4.3.1 The steering control element shall continue to be the steering control means for the operator in case of primary steering power source failure. If multiple steering control elements are provided, see requirements in 4.8.

4.3.2 When the steering control element is released, the selected wheel circle shall remain constant or become larger during travel in the forward direction.

NOTE For more information on primary steering control requirements see 8.1.2.

4.3.3 The steering system shall be designed so that the movement of the steering control element is consistent with its effect. If control operation is not obvious, an operational sign shall be provided (e.g. using symbols). Operation of the steering control element shall be in accordance with ISO 10968:— and, as applicable, with the normal functioning of the machine.

4.3.4 During machine operation, no uncontrolled steering movement shall occur due to the operation of the steering control element.

4.3.5 Steering system reliability shall be enhanced by the selection and design of components arranged so that inspection and maintenance can be readily performed.

4.3.6 Steering system disturbances shall meet the conditions given in 4.3.6.1 and 4.3.6.2.

4.3.6.1 Steering system disturbances due to other machine functions shall be minimized by appropriate arrangement and geometry. Examples of influences to be minimized are:

— axle oscillations, and

— braking torque at the wheels.

4.3.6.2 Steering system disturbances due to the influences of external forces on the machine within the applications for which the machine is designed (e.g. articulated machine navigating ruts on typical job sites) shall not significantly affect steering control.

4.3.7 All steering control elements, except for the conventional steering wheel, shall be designed, arranged (i.e. operator station layout), taken out of service (i.e. interlocked) or secured such as to reduce the possibility of unintentional activation when a person is entering or leaving the operator area.

4.3.8 Machines shall have similar steering system forces, rates and duration capability in both forward and reverse for primary and secondary steering systems. This requirement does not apply to machine with a speed <20 km/h in reverse. This may be verified by system schematics or calculations. A test in reverse is not required.

4.4 Tests with all steering systems

4.4.1 Steering columns with a steering wheel as the steering control element shall be tested according to a), b), and if applicable, c) to test the structural integrity as installed in the machine. Each test shall be conducted independently. Operator adjustable steering controls, if equipped, shall be tested at the mid-point of the steering column adjustment range.

At the conclusion of the tests, the steering systems including the adjustable controls, if equipped, shall remain functional. During the test, the adjustment position may shift provided that the adjustment controls remain functional after the test.

a) Apply a force (F) equal to 900 N as shown in Figure 2.

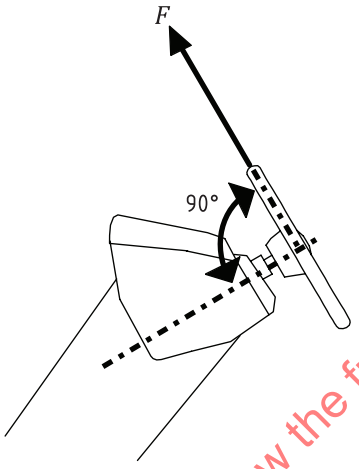


Figure 2

b) Apply a force (F) equal to 900 N as shown in Figure 3.

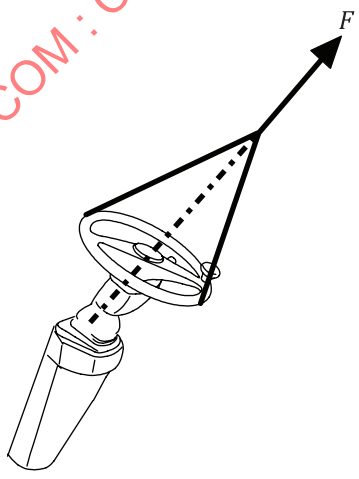


Figure 3

c) If the steering wheel can be grasped by the operator during ingress/egress from the operator station an additional test shall be performed. Apply a force (F) equal to 1 000 N as shown in Figure 4 in the direction of primary ingress.

NOTE The 1 000 N force is based on the minimum force requirement for handrails in ISO 2867.

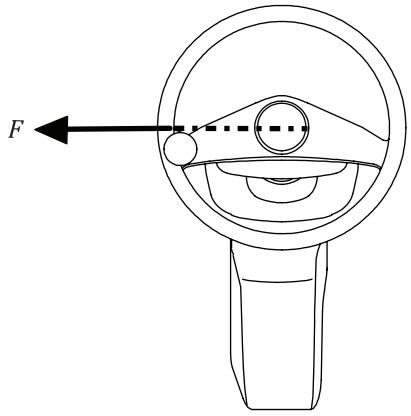


Figure 4

Other steering control elements shall meet the minimum mechanical strength requirements as given in ISO 10968:— and still remain functional for steering.

4.4.2 Steering systems shall be tested according to Clause 8. Machine wheels shall remain within the boundaries of the test courses as shown in Figures 5 and 6, excepting machines with three or more axles which include a towed semi-trailed or trailing section or unit, where the wheel path of those semi-trailed or trailing units is excluded.

4.5 Primary steering system

The primary steering system sensitivity, modulation and response shall be adequate to allow the operator to consistently maintain the machine within the intended operating path for which the machine was designed. This shall be verified by meeting the requirements of 8.1. If a steering control does not allow for modulated steering speed, the machine shall be limited to ≤10 km/h.

4.6 Secondary steering system

4.6.1 For machines equipped with a secondary steering system, the power source and related circuits for the system should be separate from other power systems and circuits. Where this is not the case, the secondary steering devices and circuits shall have priority over all other systems or circuits except for the secondary brake system, which shall be maintained at the level of performance specified in ISO 3450:2011.

4.6.2 Secondary steering performance shall be available automatically upon loss of the primary steering power source.

4.7 Powered steering system

4.7.1 Powered steering systems, if equipped with secondary steering, shall meet the conditions given in 4.7.1.1 through 4.7.1.3.

4.7.1.1 A warning device indicating a primary steering power source failure is required and shall be activated upon failure of the primary steering power source. This warning device shall readily attract the operator's attention by providing a continuous visual and audible warning. The warning may be either steady or pulsating.

4.7.1.2 If other systems are provided with power from the primary steering power source, any failure in these systems that reduces primary steering system performance shall be considered the same as a failure in the primary steering power source.

4.7.1.3 A change in ratio between the steering control element and steering output is permissible after failure of the primary steering power source, provided the requirements of 8.2 are met.

4.7.2 The power source and related circuit for the powered steering systems should be separate from other power systems and circuits. Where this is not the case, the powered steering systems shall have priority over other systems or circuits except for a secondary steering system, if equipped, and secondary brake system which shall be maintained at the level of performance specified in ISO 3450:2011.

4.7.3 Steering hydraulic circuits shall incorporate the following features:

a) pressure control devices as required to avoid excessive pressures in the hydraulic circuit;

b) hydraulic hoses shall comply with the requirements of ISO 18752:2014, except comparable markings to Clause 9 are permitted;

c) plumbing arrangements which avoid excessively tight hose bends, torsion in the installed hoses, or scrubbing and chafing of hoses. Refer to hose manufacturer's recommendation for guidance.

4.8 Steering systems with principal and alternative steering control elements

4.8.1 If more than one steering control element is to be used, the following requirements shall also be fulfilled in addition to the requirements of 4.3.

4.8.2 If a conventional steering wheel is one of the steering control elements, it shall always be activated and have a higher priority than any other steering control element and shall be considered as the principal steering control element.

4.8.3 Steering control elements that can be activated/deactivated or which have a limited speed range shall have visible or audible indication to the operator when activated.

4.8.4 If use of a steering control element is limited to a certain travel speed in accordance with the steering test specified in 8.3, the travel speed of the machine shall be limited by design to that speed when the steering control element is activated.

4.9 Ergonomic requirements

4.9.1 The steering effort shall meet the requirements given in 4.9.1.1, 4.9.1.2 and 4.9.1.3.

4.9.1.1 The steering effort for primary steering systems using a steering wheel shall not exceed 115 N when specified for the steering tests according to 8.1.

4.9.1.2 The steering effort for secondary steering systems using a steering wheel shall not exceed 350 N for the steering tests according to 8.2.

4.9.1.3 The steering actuation forces for steering control elements – apart from the steering wheel – shall not exceed the maximum control actuating forces given in ISO 10968:—, Table 2.

4.9.2 Steering control element movement to produce a given result shall not vary by more than 25 % between right and left turns up to a 30° steering angle. For machines with combination ground speed, direction and steering (i.e. skid steering) the steering output shall not vary more than 25 % between left

and right steering inputs. This may be shown by calculations. For Ackermann steering, this angle applies to the wheels toward the inside of the turn.

Exception: For compact articulated loaders that travel less than 20 km/h, the requirements above are modified to not vary more than 45 % between right and left steering.

NOTE Some regional requirements will not allow this exception.

4.9.3 When continuous moving of the steering control element (e.g. steering wheel rotation) is required to keep on changing the steering angle, the steering control movement for a given steering angle should change greater in the vicinity of the straight-ahead position.

5 Steering test course

5.1 All steering tests shall be performed on courses made on a compacted earth or paved surface which is flat and which has no more than 3 % grade in any direction.

5.2 The test course dimensions shown in Figure 5 shall be determined according to the wheel circle, wheelbase, width over wheels and machine type.

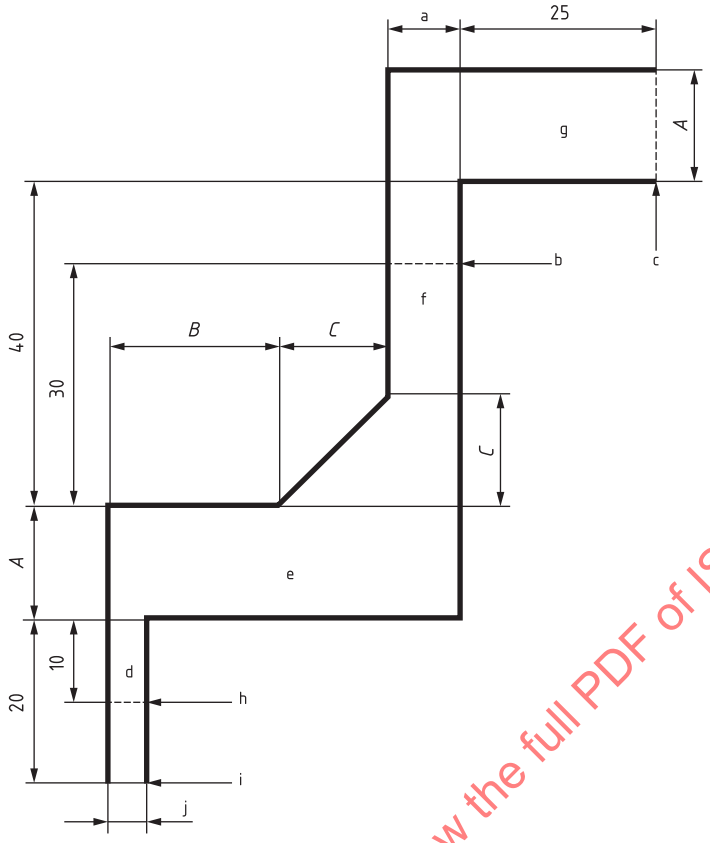
5.3 The wheelbase for a multiple-axle machine for establishing the Figure 5 test course dimensions is the distance between the most forward axle and the most rearward axle.

5.4 The mirror image of the test course shown in Figure 5 may be used.

5.5 Machines with optional tyre sizes shall be tested with tyres approved by the manufacturer having the narrowest tyre tread width.

5.6 For machines which have principal and alternative steering control elements (see 4.8), the alternative steering control elements shall also be tested per 8.3.

Dimensions in metres



Key

Course dimensions

A = 1,1 times the wheel circle or 14 m, whichever is the larger

B = 1,75 times the wheel circle or 22 m, whichever is the larger

C = twice the maximum wheelbase or 15 m, whichever is the smaller

Course length

Machines with a wheel circle of less than 12 m, all dozers, graders, rollers and compactors shall start the test at "Start 1" and terminate the test at "Finish 1". All other machines shall start the test at "Start 2"and terminate the test at "Finish 2".

a 2,5 times maximum width over wheels.
b Finish 1.
c Finish 2.
d Corridor 3.
e Corridor 4.
f Corridor 2.
g Corridor 1.
h Start 1.
i Start 2.
j 1,25 times maximum width over wheels.

Figure 5 — Steering test course

6 Machine specifications for test

6.1 Scrapers and dumpers shall be at the gross machinery mass as defined in ISO 6016:2008 including the mass of the heaviest combination of equipment and attachments approved by the manufacturer.

6.2 Machines, except those mentioned in 6.1, shall be at the operating mass as defined in ISO 6016:2008, including the mass of the heaviest combination of equipment and attachments approved by the manufacturer which produce the greatest load on the steered axles.

6.3 For testing landfill compactors, rubber tyres may be used in place of drums.

NOTE Landfill compactors can also be equipped with other equipment (e.g. sheepsfoot rollers) for compacting soil.

6.4 Rollers may be tested without vibration.

6.5 All component parameters related to steering capability shall be within the manufacturer's specifications, e.g. tyre size and pressure, hydraulic fluid pressure and flow, warning device actuation point.

7 Wheel circle test procedure

7.1 The wheel circle (used in calculating the test course dimensions for Figure 5 and 6) is determined using the outer wheel clearance diameter and the remainder of this clause. For machines with combination ground speed, direction and steering (i.e. skid steering) use turning diameter as determined in ISO 7457:1997.

NOTE In case of a crawler wheel assembly, the centre of the track contact area is considered as the centre of the wheel.

7.2 Use only the principal steering control element (e.g., steering wheel) and the primary steering system. Controls of other functions that can affect the steering path obtained shall not be used (e.g. steering brakes, grader wheel lean, grader rear bogie steer).

7.3 For machines with different right-hand and left-hand steering circles, use the smaller wheel circle in calculating the test course dimensions.

7.4 Machines with three or more axles which include towed semi-trailed or trailing section or unit(s) shall have the wheel circle determined without any semi-trailed or trailing units being towed in order to preclude steering stop interference between the trailing portions and the leading unit.

8 Steering tests

8.1 Tests with primary steering system

8.1.1 Testing of the primary steering system shall be performed using only the principal steering control element. The steering system performance shall be sufficient to maintain the machine wheels within a straight course having a width of 1,25 times the maximum width over wheels while travelling at maximum forward speed. For machines having maximum forward speed greater than 15 km/h, the test course length shall be at least 100 m long. For machines having maximum forward speed ≤15 km/h the test course length shall be at least 50 m long. Normal operator steering corrections are permissible.

8.1.2 All machines shall be driven at 8 km/h ± 2 km/h or maximum speed if lower, in a circular path with a diameter corresponding to approximately half of the largest steering angle. When releasing the steering control element, the steering angle shall not increase. Machines with a combined steering and ground speed control (e.g. skid steering) do not need to be tested to this clause provided that upon release of the combined control, the control goes to a neutral state and the machine comes to a stop.

8.1.3 For machines with a maximum speed >10 km/h the steering system shall provide sufficient capability to maintain the machine wheels (see 4.4.2) within the test course shown in Figure 5, in forward travel at a sustained speed of 16 km/h ± 2 km/h or maximum speed if lower, from the time the axes of the front wheels enter the course until the axes of the front wheels reach the end of the course. The steering effort shall be recorded and shall meet the requirements in 4.9.1.1. Several practice runs are permitted to

allow the operator to develop an even, modulated application of muscular force on the steering control element.

8.1.4 Machines with a maximum speed ≤10 km/h shall meet either the performance requirements of 8.1.3 associated with the steering course illustrated in Figure 5, or the performance requirements of 8.3.2 and 8.3.3 associated with the steering test course in Figure 7.

8.1.5 If the machine is equipped with secondary steering system the warning device indicating a primary steering source failure shall be tested for proper functioning in accordance with 4.7.1.1.

8.2 Tests with secondary steering system

8.2.1 The primary steering power source shall be disconnected if engine-driven because engine power is employed to drive the machine through the test courses specified in 8.2.3, 8.2.4, 8.2.5 and 8.2.7.

8.2.2 Secondary steering power source available at the beginning of any secondary steering test run shall be no more than is normally available at the instant a primary steering power source failure is indicated.

8.2.3 Testing of the secondary steering system shall be performed using only the principal steering control element. The secondary steering system performance shall be sufficient to maintain the machine wheels (see 4.4.2) within a straight course 100 m long and having a width of 1,25 times the maximum width over wheels while travelling at 16 km/h ± 2 km/h. Normal operator steering corrections are permissible.

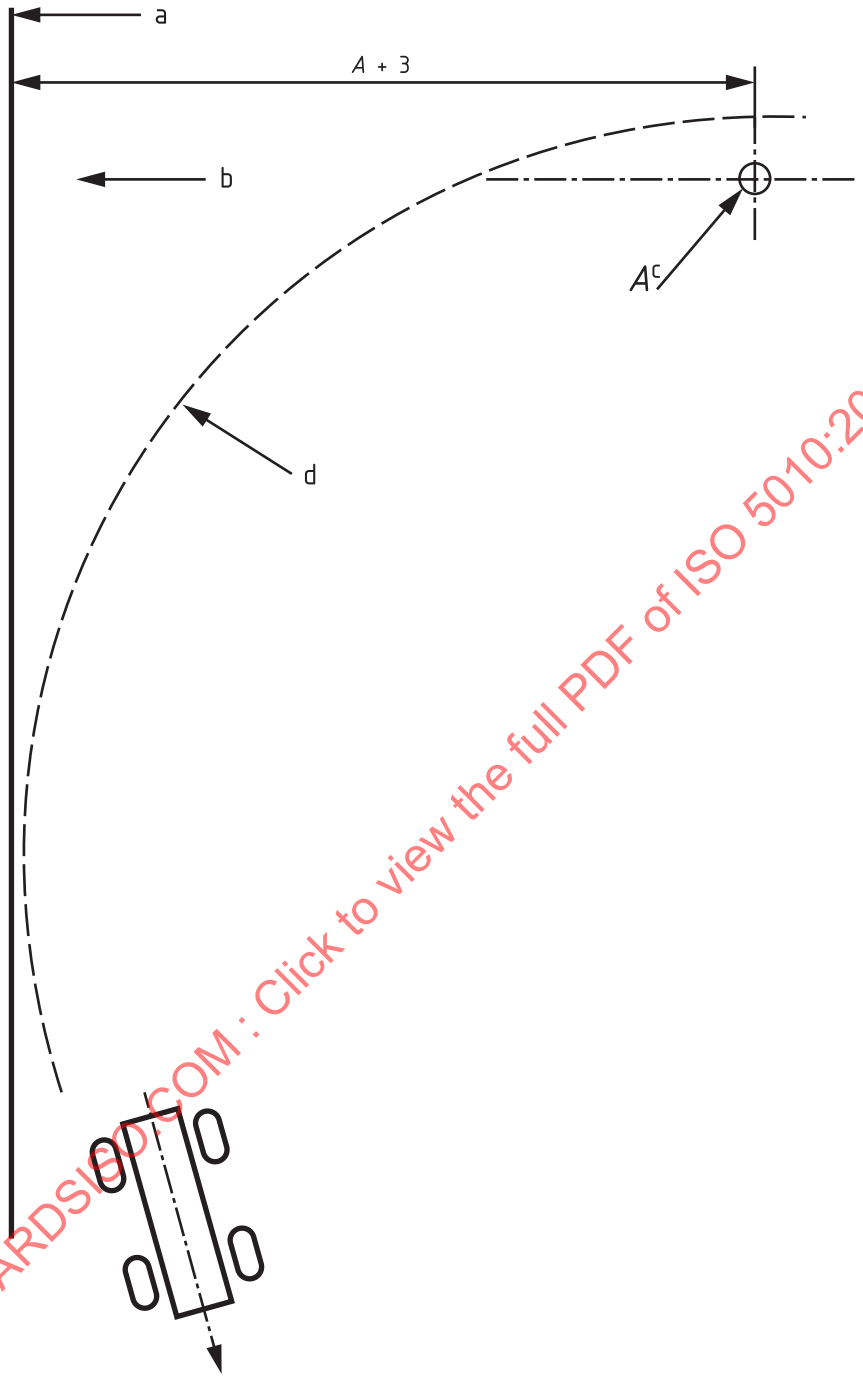
8.2.4 Secondary steering shall provide an adequate steering force and steering duration to maintain the machine wheels (see 4.4.2) within the test course (as determined from Figure 5) at 8 km/h ± 2 km/h with the machine moving continuously at that speed from the time the axes of the front wheels enter the course until the axes of the front wheels reach the end of the course.

8.2.5 Secondary steering shall provide an adequate steering force and steering rate to maintain the machine wheels (see 4.4.2) within the test course (as determined from Figure 5) at 16 km/h ± 2 km/h with the machine moving continuously at that speed from the time the axes of the front wheels enter the course until the axes of the front wheels reach the end of the course.

8.2.6 During the tests according to 8.2.4 and 8.2.5, the steering effort shall be recorded and shall meet the requirement in 4.9.1.2. Several practice runs are permitted to allow the operator to develop an even, modulated application of the muscular force on the steering control element.

8.2.7 The secondary steering response test specified in this clause shall be conducted by driving the machine through the test course as shown in Figure 6, at 16 km/h ± 2 km/h. This test shall be conducted with the mirror image of the course shown in Figure 6 if the Figure 5 test course was conducted with its own mirror image. Enter the test course with the secondary steering system capability as normally available. Initiate a turn at point A, as shown in Figure 6. The start of steering control actuation should trigger a ground marker located under the front axle, and simultaneously simulate a failure of the primary steering power source. The machine shall complete a 90° turn with the wheel circle remaining within the boundary specified.

Dimensions in metres



Key

A 1,1 times the wheel circle or 14 m, whichever is the larger

a Perpendicular to original direction of travel.

b Original direction of travel.

c Point A: forward axle location at initiation of steering control movement.

d Outside line of wheels.

Figure 6 — Secondary steering response

8.3 Steering test with alternative steering control elements

8.3.1 Alternative steering control elements shall be tested according to 8.1.

8.3.2 If the machine operated with the alternative steering control element cannot meet the requirements of 8.1.3 then it shall be tested using the test course in Figure 7. The machine shall limit the maximum speed for use of the alternative steering control to the highest speed that the machine can make it through the Figure 7 course using the alternative steering control. This speed shall be the highest speed permitted to be used for the alternative steering control. The machine shall be tested under the following conditions:

— The machine shall be controllable as a comparable machine with a steering wheel as the steering control element.

— The maximum speed shall be realized in Zone 1. The machine shall enter Zone 2 centred between the cones and parallel to the course. Speed may only be reduced after the front edge of the machine has reached the first group of cones.

— In Zone 2 the operator is permitted to do anything that is required for keeping or reducing speed, except for using the brakes. The machine shall swerve around the single cone; additional manoeuvres are not permitted (e.g. a loop turn).

— In Zone 3 the operator may use the brakes after the wheel centre of the front wheel has passed the cones. The machine shall be able to stay within the course until coming to a complete stop.

— None of the cones shall be run over.

8.3.3 Machine wheels shall remain within the boundaries of the test course as shown in Figure 7, excepting machines with three or more axles which include a towed semi-trailed or trailing section or unit(s), where the wheel path of those semi-trailed or trailing units is excluded (other than avoiding the obstacle).